C6.5 Abutments

C6.5.1 General

C6.5.1.1 Policy overview

C6.5.1.1.1 Integral

Parameter study and discussion, 16 August 2007

In order to adjust integral abutment policy to LRFD and the latest ISU research (Abendroth and Greimann 2005) a parameter study was conducted to determine the effects of bridge length, end span length, skew, and prebore depth. For PPCB bridges the study specifically worked with the new A-D and BTB-BTD beams with an end span of maximum beam length. For CWPG members the basic condition was taken to be an end span of 150 feet or the maximum end span that would result in a pile structural resistance at Structural Resistance Level – 1, the LRFD equivalent to a 6 ksi axial stress under service load design.

In LRFD there is a single check for combined forces (axial load and bending) rather than the two (stability and yield) in service load design. The parameter study included the LRFD combined forces check and a ductility check (Abendroth and Greimann 2005). Generally the LRFD combined forces check gave results less conservative but similar to those from the stability and yield checks in service load design. A different, more conservative way of evaluating the effects of pile skew (similar to Abendroth and Greimann 2005), however, gave results essentially the same as those for past parameter studies.

With the latest ISU recommendations for ductility, the ductility check generally will not control the design, but use of the recommended seismic plate ratios requires that several H-pile shapes be avoided. Ratios for flange plates $b_f/2t_f$ above 11.0 do not work for Grade 50 steel, and the policy recommendation is to set an upper limit of 10.5, but either limit results in the same list of acceptable H-piles: HP 10x57, HP 12x74, HP 12x84, HP 14x102, and HP 14x117. The HP 14x102 shape should be avoided because it generally is not readily available.

Because of the less conservative biaxial bending and ductility checks, bridges with minimal skew may have greater lengths than present policy allows. Limits other than bridge length may be appropriate, however. Considering the type and performance of present pavement joints, the maximum bridge length for zero skew was set for approximately 1.55 inches maximum movement each way, assuming that the bridge is fixed at mid-length. At the maximum bridge length the pavement joints should be of the CF-3 type [OD SRP RH-52 and RK-20]. At shorter bridge lengths the CF-2 or CF-1 joints should be used within the guidelines on the standard road plan [OD SRP RK-20].

In general, the parameter study verified the previous study conducted for the service load design manual. The information for the Bridge Design Manual tables, however, was modified to better fit the LRFD format.

Reference

Abendroth, R.E. and Greimann, L.F. (2005) *Field Testing of Integral Abutments, Final Report HR-399.* Center for Transportation Research and Education (CTRE), Iowa State University, Ames, Iowa. Available online at <http://www.ctre.iastate.edu/reports/hr399.pdf>.

LRFD Integral Abutment Example

Given: Four-span PPCB bridge, 105-120-120-105-foot spans, 450-foot length, 20-degree skew
Five-BTC cross section, beam spacing 9'-3
Soil profile: 30 feet stiff silty clay, N = 6; sound bedrock, N = 210
Soils Design Section recommendation: end bearing on rock, maximum allowable in soils chart
Total abutment factored vertical load = $\Sigma\eta_i\gamma_iP_i$ = 1200 kips
Use HP 10x57 for integral abutment.

Nominal structural resistance for HP 10x57 at SRL-2, maximum in end bearing: P_n = 365 kips [BDM Table 6.2.6.1-1]. Note, however, that this maximum may not be permissible based on integral abutment limits, which may be less than SRL-2 [BDM Table 6.5.1.1.1-1].

Check maximum bridge length. Interpolate for 20-degree skew [BDM Table 6.5.1.1.1-1].

L_{max} = 525 + [(20-15)/(30-15)](475-525) = 508 feet; 508 feet > 450 feet, OK

Check integral abutment limit on nominal structural resistance.

Table 6.5.1.1.1-1 indicates that interpolation will not lead to 365-kip resistance, but shorter-than-maximum end span will permit some increase in extrapolated value.

Try 10-foot prebore with interpolation for skew; extrapolate for resistance with 120-foot end span.

P_n = 324 + [(20-15)/(30-15)](243-324) = 297 kips

Increase P_n for shorter-than-maximum end span.

P_n = (120/105)(297) = 339 kips, which is close to 365 kips. (Using a 15-foot prebore would permit the full 365 kips but, as the next step shows, the additional prebore would not reduce the number of piles.)

Determine number of piles

Number of piles, n = $\Sigma\eta_i\gamma_iP_i/\varphi_cP_n$ = 1200/(0.6*339) = 5.9, use 6

Check minimum: 5 beams require 5 piles, OK; maximum pile spacing is 8 feet, <u>use 6.</u>

Plan sheet bearing based on SRL-2 = 75*(339/365)(5.9/6) = 68.50, say <u>69 tons</u> [BDM Table 6.2.6.1-1]

By observation geotechnical resistance will be more than adequate. No drivability analysis is required during design because the piles have been limited to Structural Resistance Level - 2.

CADD Note E820 on plans: THE DESIGN BEARING FOR THE ABUTMENT PILES IS 69 TONS.

Methods Memo No. 79: Integral Abutment Piles
24 July 2003

Information from representatives of the companies supplying steel H-piles, from the American Institute of Steel Construction (AISC), and from mill reports on Iowa DOT projects all indicate that the yield stress for H-piles is consistently 50 ksi (345 MPa) or greater. Iowa DOT Standard Specifications require A36 (250 MPa) steel, but the ASTM A36 (250 MPa) specification has no upper limit on yield. Present pile manufacturing processes depend on scrap steel, which includes strength-enhancing elements that are not easily removed, and therefore it is difficult for manufacturers to produce steel with a yield stress below 50 ksi (345 MPa).

Although the higher yield stress improves the stability and yield checks recommended by HR-273 and Methods Memo No. 23 (the current basis for integral abutment pile design), the higher yield stress worsens the ductility check for partially compact shapes. As the yield stress for shapes increases from 36 to 50 ksi, (250 to 345 MPa) the allowable or limiting $b_f/2t_f$ ratio for compact flanges reduces from 10.83 to 9.19, and the ratio for noncompact flanges reduces from 15.83 to 13.44. Therefore piles with a 50 ksi (345 MPa) yield are less likely to be able to meet the ductility demand for integral abutments.

Because piles that are noncompact at 50 ksi (345 MPa) yield have no allowable plastic rotation capacity, the following pile sections are prohibited for use in integral abutments:

- HP 12x53 (HP 310x79)
- HP 14x73 (HP 360x108)

These pile sections, however, may be used for stub abutments and pier footings.

The preferred pile section for integral abutments for pretensioned prestressed concrete beam and continuous welded plate girder shall be HP 10x57 (HP 250x85), a compact shape at 50 ksi (345 MPa) yield. In addition to providing ample ductility, use of the HP 10x57 (HP 250x85) section at 36 ksi (250 MPa) will increase the allowable pile capacity for friction piles to 50 tons (6 ksi * 16.8 in^2) or 443 kN (41000 kN/m^2 * 0.0108 m^2) and the resulting pile spacing, which often has been at the minimum for the HP 10x42 (HP 250x62) section. However, the friction bearing capacity per foot of pile for the HP 10x57 (HP 250x85) section is the same as for the HP 10x42 (HP 250x62), and on some sites HP 10x57 (HP 250x85) piles will need to be longer to achieve full bearing. HP 10x42 (HP 250x62) piles may continue to be used for continuous concrete slab bridges within the limits set in the updated Bridge Design Manual (Table 6.5.1.1.1).

In addition, exceeding the limits for integral abutments in article 6.5.1.1.1 of the Design Manual (Methods Memo No. 23) is discouraged. Special cases brought to the attention of the Chief Structural Engineer will be checked for ductility assuming a pile yield stress of 50 ksi (345 MPa) (but all other checks will be on the basis of 36 ksi (250 MPa)).

In addition to the new office policy of using HP 10x57 (HP 250x85) piles in integral abutments, the office is recommending that on projects where the HP 10x57 (HP 250x85) is used that no other 10 inch (250 mm) pile size be used. This policy is to prevent similar 10-inch pile (250 mm) sizes from being used in the wrong location.

See attached sheets for changes to the Bridge Design Manual Article 6.2 Piles and Article 6.5 Abutments.

This policy should be applied to bridge projects currently under design that have not been detailed.

Methods Memo No. 86: New Policy for Bridge Approach Slabs
23 October 2003

See C6.5.4.1.2.

Methods Memo No. 93: Approach Slab Responsibilities with Downdrag
31 March 2004

See C6.5.4.1.2.

C6.5.1.1.2 Stub

Methods Memo No. 86: New Policy for Bridge Approach Slabs
23 October 2003

See C6.5.4.1.2.

Methods Memo No. 93: Approach Slab Responsibilities with Downdrag
31 March 2004

See C6.5.4.1.2.

Methods Memo No. 195: Stub Abutment Design Behind MSE Walls. Revision to Article 6.5.1.1.2 LRFD Bridge Design Manual
1 October 2008

See C11.2.2.

C6.5.1.2 Design information

C6.5.1.3 Definitions

C6.5.1.4 Abbreviations and notation

C6.5.1.5 References

C6.5.2 Load application

C6.5.2.1 Dead

Methods Memo No. 57: Abutment Piling Design, PPCB Bridges
5 November 2001

When determining the number of abutment piling for a prestressed concrete beam bridge design, allow for continuity of the superstructure when applying the dead load 2 and live loads.

C6.5.2.2 Live

Methods Memo No. 57: Abutment Piling Design, PPCB Bridges
5 November 2001

See C6.5.2.1.

C6.5.2.3 Dynamic load allowance

C6.5.2.4 Centrifugal

C6.5.2.5 Braking force

C6.5.2.6 Earth pressure

C6.5.2.7 Live load surcharge

C6.5.2.8 Earthquake

C6.5.3 Load application

C6.5.3.1 Limit states

C6.5.3.2 Integral abutments

C6.5.3.3 Stub abutments

C6.5.4 Abutment analysis, design, and detailing

C6.5.4.1 Integral abutments

C6.5.4.1.1 Analysis and design

Methods Memo No. 14: Prebore Length for Integral Abutments
13 September 2001

See C6.2.4.

Methods Memo No. 211: Office Guidelines for Mass Concrete and Temperature and Shrinkage Reinforcing
1 September 2009

See C6.6.4.1.3.1.

C6.5.4.1.2 Detailing

Methods Memo No. 107: Integral Abutment and Pier Cap Detailing
6 June 2005

For integral abutments and pier caps on skews and / or superelevation, consider sloping the bottom of the abutment footing or pier cap if the difference in the low to high step elevations is over 1’-6 (450 mm).

In addition, column heights for frame piers on piling should be equal unless more than 3’-0 (900 mm) of additional excavation is required. If over 3’-0 (900 mm) additional excavation would be required discuss the situation with your section leader.

The changes shall be made to all bridges currently being detailed.

Methods Memo No. 52: Use of p3 Bars in Integral Abutments
18 October 2001

There has been some confusion on the use of p3 reinforcing bars in integral abutments. The office policy on use of p3 bars should be as follows.

1. Use p3 bars in integral abutments of bridges using standard C or D prestressed sections with steel H piles.
2. Use p3 bars in integral abutments of all steel bridges using steel H piles.

p3 bars are not required in integral abutments of bridges using standard A or B prestressed sections, in concrete slab bridges or in stub abutment bridges.

Please include this revision in all projects that are currently being developed.

Methods Memo No. 105: Use of Epoxy-Coated Reinforcing Steel
28 March 2005

The cost difference between black and epoxy-coated reinforcing has decreased to the point that expanded use of epoxy-coated bars will have a minimal impact on the overall cost of the bridge. Therefore, the Office of Bridges and Structures has adopted the following new policy regarding the use of epoxy-coated reinforcing steel:

1. All reinforcing bars in bridge abutments shall be epoxy coated including all reinforcing bars in the abutment seat, backwall and wing extensions.
2. All reinforcing bars in the intermediate concrete diaphragms for prestressed beam bridges shall be epoxy-coated.

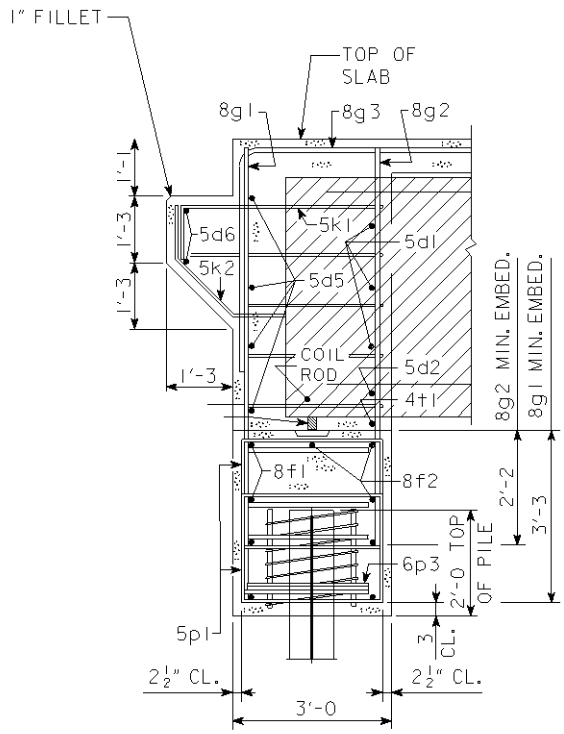
This policy shall be implemented for all steel girder bridges, non-standard prestressed and non-standard concrete slab bridges where detailing has not yet started. Where bridge standard sheets (not yet modified to meet this policy) are applicable they shall be used as is. Current bridge standard sheet will be updated, to be consistent with this policy, at later date.

The office policy for using epoxy-coated reinforcing steel in piers will not be changed at this time.

Methods Memo No. 86: New Policy for Bridge Approach Slabs (Modified by MM No. 93)
23 October 2003

To help improve the construction of the bridge approach slabs on highway projects, the Office of Bridges and Structures will start including the approach slab details in the bridge plans. The details will be provided by Design and include any details, standard references, and bid tabs for the bridge approach slabs. These details will be provided along with the details that are normally provided for the new bridge plans (traffic control, pollution preventions, etc.)

Design is currently updating the approach slab details and will be including the standards in their updates for April 04 lettings. Reinforced approach slab details should be included in all bridge plans starting with the April 04 lettings. Prior to April 04, some bridge projects may be required to have approach slab details included with the bridge plans. For bridges using the new approach slab, the abutment paving notch shall also be updated (See details below). Check with your section leader to see what projects are to be included.



TYPICAL SECTION

Methods Memo No. 93: Approach Slab Responsibilities with Downdrag (Modification to MM No. 86)
31 March 2004

Recently a Method's Memo was sent out addressing a change in policy for approach slabs (MM No. 86). This memo required that the approach slab details be included in the bridge plans. Since the memo was sent out, an exception to the change was brought to my attention. The exception is situations where settlement is a problem and downdrag forces need to be included in the substructure piling design. If settlement is a problem, then it may be advantages to delay the approach slab placement until the pavement is placed. This delay would allow some of the settlement to take place before the approach slabs are installed.

Therefore when downdrag is required in the bridge piling design, Design shall be informed of the settlement problem and the approach slab sheets shall be included in the Design's plans. In addition, the temporary paving block shall be provided in the plans.

C6.5.4.2 Stub abutments

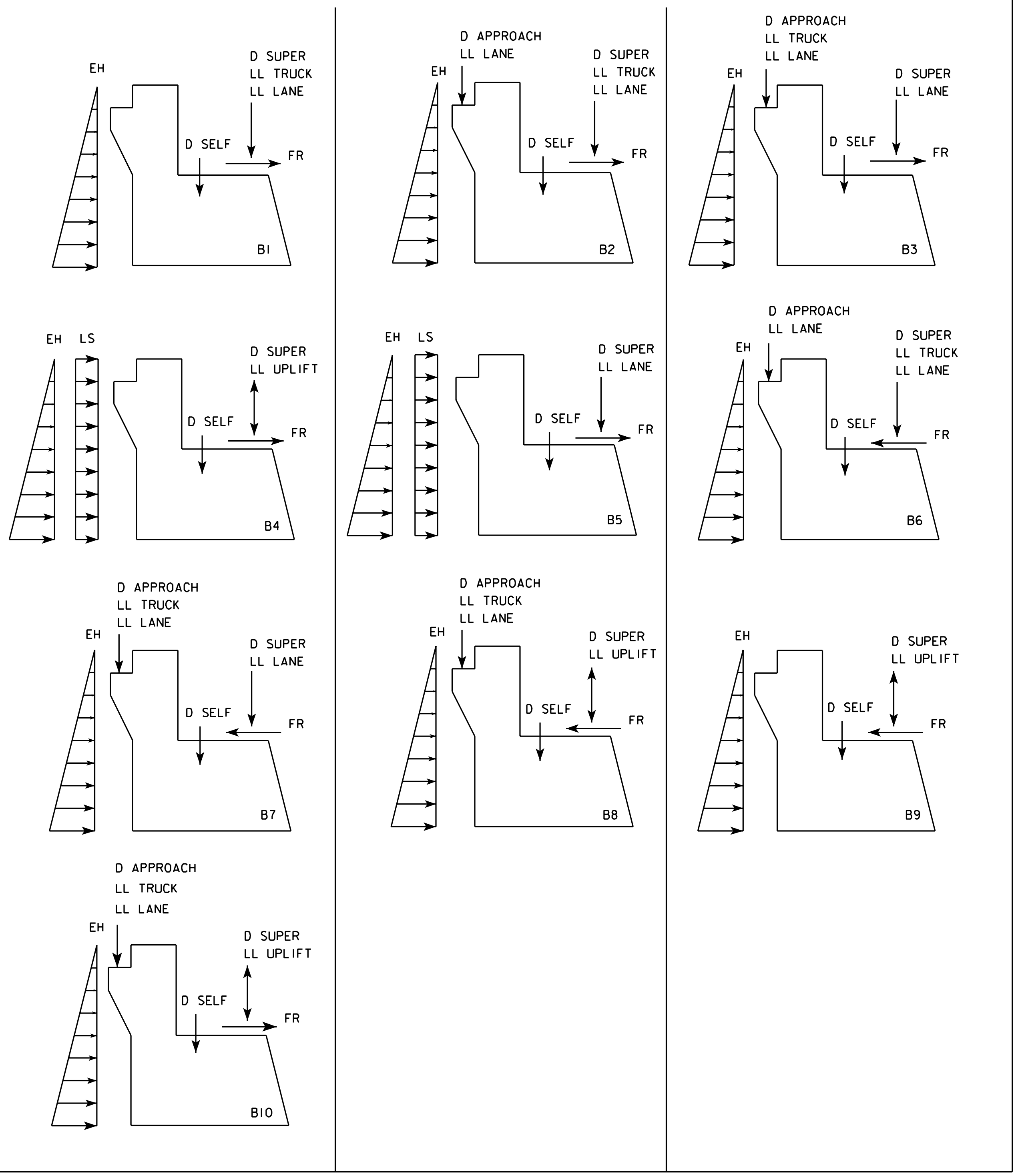
C6.5.4.2.1 Analysis and design

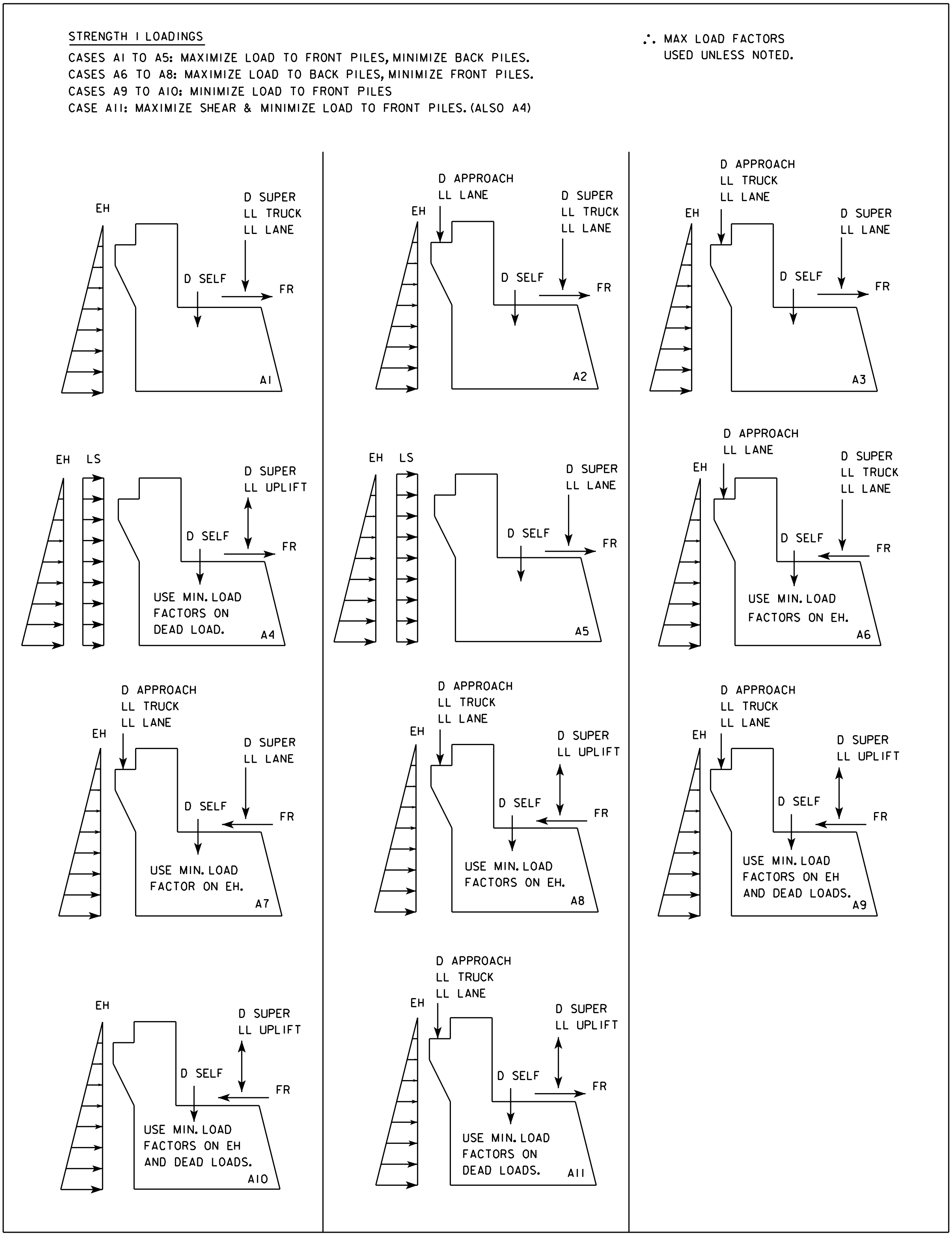
The following two figures for stub abutment load cases illustrate the typical cases that the designer should consider. The cases shown are not necessarily all of the cases to be considered for a specific bridge, and the designer should be on the alert for load cases to add or remove based on the bridge under design.

SERVICE I LOADINGS

CASES B1 TO B5: MAXIMIZE LOADS TO FRONT PILES, MINIMIZE BACK PILES.
CASES B6 TO B8: MAXIMIZE LOADS TO BACK PILES, MINIMIZE FRONT PILES.
CASE B9: MINIMIZE LOADS TO FRONT PILES.
CASE B10: MAXIMIZE SHEAR & MINIMIZE LOADS TO FRONT PILES. (ALSO B4)

∴ LOAD FACTORS ARE 1.00




STRENGTH I LOADINGS
CASES A1 TO A5: MAXIMIZE LOAD TO FRONT PILES, MINIMIZE BACK PILES.
CASES A6 TO A8: MAXIMIZE LOAD TO BACK PILES, MINIMIZE FRONT PILES.
CASES A9 TO A10: MINIMIZE LOAD TO FRONT PILES
CASE A11: MAXIMIZE SHEAR & MINIMIZE LOAD TO FRONT PILES. (ALSO A4)
∴ MAX LOAD FACTORS USED UNLESS NOTED.
EH
D SUPER
LL TRUCK
LL LANE
D SELF
FR
A1
D APPROACH
LL LANE
EH
D SUPER
LL TRUCK
LL LANE
D SELF
FR
A2
D APPROACH
LL TRUCK
LL LANE
EH
D SUPER
LL LANE
D SELF
FR
A3
EH
LS
D SUPER
LL UPLIFT
D SELF
FR
USE MIN. LOAD FACTORS ON DEAD LOAD.
A4
EH
LS
D SUPER
LL LANE
D SELF
FR
A5
D APPROACH
LL LANE
EH
D SUPER
LL TRUCK
LL LANE
D SELF
FR
USE MIN. LOAD FACTORS ON EH.
A6
D APPROACH
LL TRUCK
LL LANE
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D SUPER
LL LANE
D SELF
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USE MIN. LOAD FACTOR ON EH.
A7
D APPROACH
LL TRUCK
LL LANE
EH
D SUPER
LL UPLIFT
D SELF
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USE MIN. LOAD FACTORS ON EH.
A8
D APPROACH
LL TRUCK
LL LANE
EH
D SUPER
LL UPLIFT
D SELF
FR
USE MIN. LOAD FACTORS ON EH AND DEAD LOADS.
A9
EH
D SUPER
LL UPLIFT
D SELF
FR
USE MIN. LOAD FACTORS ON EH AND DEAD LOADS.
A10
D APPROACH
LL TRUCK
LL LANE
EH
D SUPER
LL UPLIFT
D SELF
FR
USE MIN. LOAD FACTORS ON DEAD LOADS.
A11

Methods Memo No. 211: Office Guidelines for Mass Concrete and Temperature and Shrinkage Reinforcing
1 September 2009

See C6.6.4.1.3.1.

C6.5.4.2.2 Detailing

Methods Memo No. 105: Use of Epoxy-Coated Reinforcing Steel
28 March 2005

See C6.5.4.1.2.

Methods Memo No. 86: New Policy for Bridge Approach Slabs
23 October 2003

See C6.5.4.1.2.

Methods Memo No. 93: Approach Slab Responsibilities with Downdrag
31 March 2004

See C6.5.4.1.2.

C6.5.4.3 Wing walls

C6.5.4.3.1 Analysis and design

Methods Memo No. 121: Use of Special Concrete Mixes on Bridges
8 July 2005

See C5.2.4.1.1.2.

Methods Memo No. 33: Wing Extensions for C-Beams
11 July 2001

For prestressed beam bridges that use the C-beam standard the following policy change has been made. When using the C-beam, the abutment standards for the D-beam with the 5 ft wing extension should be used.

There have been some problems in the field with slope stability around the abutment wings on some prestressed bridges. This has been more severe for our bridges that use the C beam standards because of steeper than 2:1 slope that occurs when using just the 7 ft. wing. Using the additional 5-ft wing extension will allow for a flatter slope around the wing.

This change should be incorporated into all bridges let after October 1st, 2001.

C6.5.4.3.2 Detailing

Methods Memo No. 105: Use of Epoxy-Coated Reinforcing Steel
28 March 2005

See C6.5.4.1.2.

Appendix for obsolete and superseded memos

Methods Memo No. 23: Length Limits and Prebore Depths for Integral Abutment Bridges
30 October 2002 (Edited 29 January 2003)

There has been considerable interest in the Office of Bridges and Structures in reexamining the length limits and analysis requirements for integral abutment bridges. For 178 overhead bridges designed by the office recently, about 70% meet present criteria for use of integral abutments without special investigation, but the limits could be extended to include a greater percentage, perhaps as much as 90%. Because of the benefits of jointless bridges the office would prefer to extend the use of integral abutments wherever feasible.

Based on consideration of the HR-273 report and addendum analysis with minor modifications, field testing described in the report for HR-292, and simple parameter studies, the following new limits for standard integral abutments are listed in the table. The new limits are for the three typical bridge types—pretensioned prestressed concrete beam (PPCB), continuous concrete slab (CCS), and continuous welded plate girder (CWPG)—designed by the office and the following conditions:

1. Integral abutments are placed at both ends of the bridge.
2. All abutment piles are A36 steel, HP 10x42 (HP 250x62) with webs oriented parallel with the abutment. For skews greater than 30 degrees, piles should be oriented for weak axis bending.
3. Each abutment pile is loaded to 37 tons (329 kN) or less.
4. All abutment piles for bridges longer than 130 feet (39.620 m) are placed in prebored holes 10-feet (3.050 m) deep and filled with bentonite slurry. (Prebored holes need not be used for bridges 130 feet (39.620 m) or less in length.) Bentonite slurry is assumed to provide no bearing capacity or lateral support for the piles.
5. Setting factors of 1.50 for concrete and 1.33 for steel bridges magnify thermal movement. The setting factors provide for construction temperatures of 25 to 75 degrees-F (-4 to 24 degrees-C).
6. All abutment piles are a minimum length of 2.5 times the prebore depth, from bottom of footing to bearing end.
7. Bridges have approximately parallel abutments and piers.
8. Bridges are straight or horizontally curved with straight beams or girders.
9. The controlling design condition is either (a) Service Load Group 4 with the stability, yield, and ductility checks of the HR-273 addendum Alternative 2 at 125% stress, or (b) Service Load Group 1 with stability and yield checks of the HR-273 addendum Alternative 1 (or 2) at 100% stress.

Superstructure Material	**Length and Skew Limits for Standard Integral Abutments**	**Maximum End Span**
Concrete (PPCB and CCS)	575 (175.260 m) feet at 0-degree skew to 425 feet (129.540 m) at 45-degree skew, with linear interpolation of length for intermediate skew	110 feet (33.520 m)
Steel (CWPG)	400 feet (121.920 m) at 0-degree skew to 300 feet (91.440 m) at 45-degree skew, with linear interpolation of length for intermediate skew	85 feet (25.910 m)

The following uses of integral abutments also are permitted:

1. If a working integral abutment is feasible at only one end of a bridge, the maximum length limit for the bridge shall be one-half the limit in the table, with no change in maximum end span length.
2. The office policy of allowing timber piles in integral abutments for bridge lengths to 200 feet (60.960 m) and skews to 30 degrees remains in effect. See Standard Sheets 2078-2085 (M2078-M2085).

3. If HP 10x42 piles are loaded to 55 tons (489 kN), the maximum end span length shall be reduced by 10 feet (3.050 m).
4. Prebored holes may be increased in depth to 15 feet (4.570 m) to reduce or eliminate downdrag forces.
5. For two-span bridges, prebored hole depth may be increased to permit longer end spans. For PPCB bridges, for each 1-foot (300 mm) increase in prebore depth, maximum end span may be increased by 15 feet (4.570 m), but the maximum end span length shall be limited to 140 feet (42.670 m). For CWPG bridges, for each 1-foot (300 mm) increase in prebore depth, maximum end span may be increased by 8 feet (2.440 m), but the maximum end span length shall be limited to 125 feet (38.100 m).
6. In cases where a MSE retaining wall is used near an integral abutment, each pile shall be sleeved with a corrugated steel pipe (CSP) to control compaction near the pile as the embankment and MSE wall are built. At the top, the CSP sleeve shall be blocked temporarily with framing lumber so that the pile remains at the center of the sleeve. The CSP sleeve shall be filled with sand to the elevation of the bottom of prebore and then with bentonite to the top of the CSP sleeve.
7. For bridges that exceed the limits, request an exception from the Chief Structural Engineer. (Because of the interest in extending the limits, especially for end spans of steel bridges, piles in one or more bridges may be monitored in the near future.)

The limits were drawn from parameter studies for a simple pile model using Conditions 1) through 9) for typical bridges with a 40-foot (12.000-meter) roadway. The limits are larger than those used by the Iowa DOT in the past. With setting factors the limits usually are less than the ±1.5-inch (±38-mm) limit for lateral pile displacement given in the AASHTO LRFD specifications. (The AASHTO limit is general and not specifically for integral abutments.)

Previous FHWA guidelines suggested limits for lengths of bridges with integral abutments. The guidelines have expired and have not been replaced.

The following were sources of conservatism in the parameter studies:

- Setting factors magnified the temperature displacement of the piles and the bending stresses in the piles. The setting factors allow for a reasonable range of construction temperatures, 25 to 75 degrees-F (-4 to 24 degrees-C).
- Soil at abutments was assumed to be stiff clay with N=40.
- Piles were assumed to be freestanding in the prebored holes and subject to impact.
- The overall stability term correction ($C_m/1\text{-}f_a/F'_e$) was limited to one or more as in the HR-273 Addendum.
- In most cases bridge lengths were rounded down to the nearest 25-foot (7.620-meter) increment.
- The check under Service Load Group 1 (not in HR-273) sometimes was the controlling case, with a 10 to 15% increase in capacity demand over Service Load Group 4.

The proposed limits extend to include the two Iowa steel and concrete bridges approximately 325 feet (99.060 m) long with 30- and 45-degree skews that were tested under HR-292. The proposed limits generally are more liberal than the limits in surrounding states. Most states do not permit integral abutments for skews greater than 30 degrees. Kansas, however, apparently sets no limit for skew and allows concrete bridges nearly 500 feet (152.400 m) long and steel bridges nearly 300 feet (91.440 m) long.

Researchers at Iowa State University are completing the final report on testing of two Iowa PPCB bridges with integral abutments, and the report should be available in late 2002. A preliminary presentation on the testing indicated no significant problems with the bridges, one of which exceeded the present Iowa DOT length limit.

References:

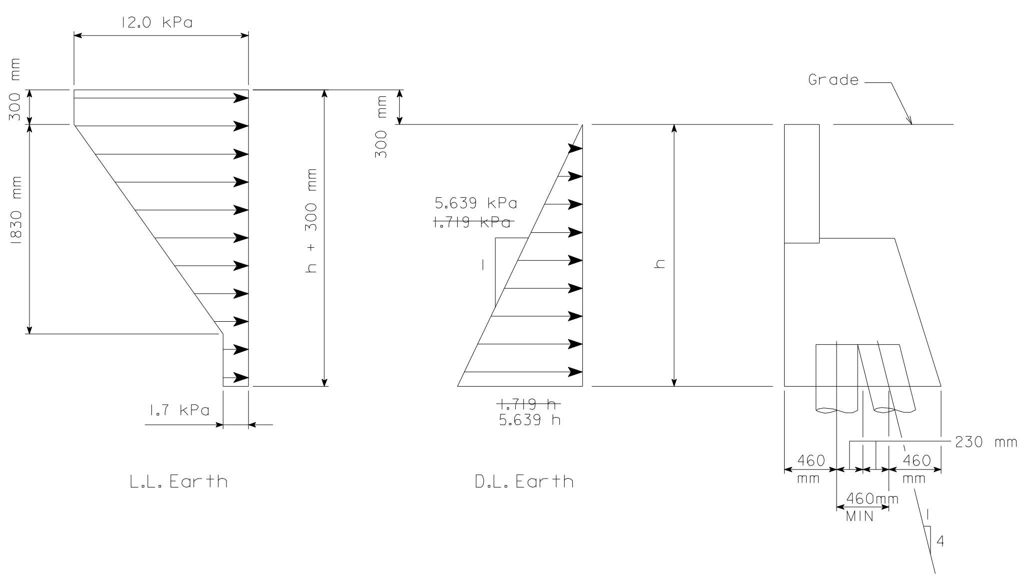
Greimann, L.F., R.E. Abendroth, D.E. Johnson, and P.B. Ebner. *Final Report, Pile Design and Tests for Integral Abutment Bridges, HR-273, and Addendum.* Ames: Iowa Department of Transportation and College of Engineering, Iowa State University, 1987.

Girton, D.D., T.R. Hawkinson, and L.F. Greimann. *Final Report, Validation of Design Recommendations for Integral Abutment Piles.* Ames: Iowa Department of Transportation and College of Engineering, Iowa State University, 1989.

Tucker, W.D. "Integral Abutment Investigation and Excel Spreadsheet." Ames: Office of Bridges and Structures, Iowa Department of Transportation, 1994.

Methods Memo No. 116: Correction to Figure 6.5.2.5 in 6.5 Abutments of the Bridge Design Manual 24 March 2005

The following error has been found in Figure 6.5.2.5 metric version in section "6.5 Abutments" of the Bridge Design Manual. The soil pressure conversion from English to metric should be 5.639 kPa / m of height instead of the 1.719 kPa / m of height that was shown. Please review any design calculations where this values has been used and make the appropriate correction. See corrected figure below.



L.L.E. is applied over the width of loaded lanes and is subject to reduction A.A.S.H.T.O. Art. 3.12.1